COMPUTATION OF TOPOGRAPHIC MULTIPLIERS

D.A.Paterson and J.D.Holmes
(CSIRO, Division of Building,Construction and Engineering)

INTRODUCTION

This paper describes some results of a computational study of wind flow over two-dimensional ridges and escarpments. The study was carried out to better define the "Topographic Multipliers" for mean and gust wind speeds required for the design of communication towers and buildings.

The definition of Topographic Multiplier adopted for the study is that used in the Australian Standard [1], as follows:

$$\text{Topographic Multiplier} = \frac{\text{(Wind speed at height z above hill)}}{\text{(Wind speed at height z upwind)}} \qquad (1)$$

This definition applies to both the gust wind speed, and to the mean wind speed.

The background to the rules for the Multipliers in the Australian Standard is discussed in the Commentary to the Standard [2]. Several simplifying assumptions were made in drawing up these rules. These have been investigated in the present study.

COMPUTATIONAL TECHNIQUES

Modelling of the wind flow was carried out by obtaining solutions of the time-averaged Navier-Stokes equations. The time-averaged equations contain six extra terms that are related to the root-mean-square (r.m.s.) velocities; these are created when the time averaging is carried out. In the approach used, these extra terms were derived from the turbulent kinetic energy, k, which is half the sum of the squares of the r.m.s. velocity components, and from the rate of dissipation of the turbulent kinetic energy, e. k and e were calculated from two further equations. This method of modelling the turbulence is known as the "k-e" turbulence model [3,4].

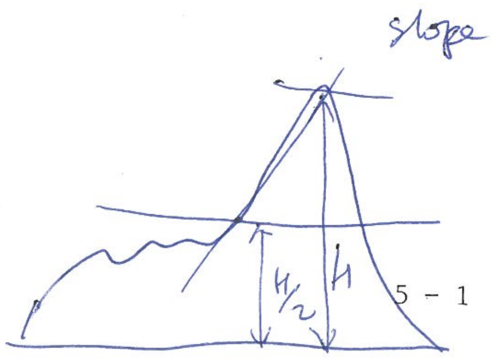
In the present work, calculation of the peak gust wind speed, as well as the mean wind speed was required.

The peak gust wind speed was obtained from:

$$\hat{u} = \bar{u} + 3.7\sqrt{\overline{u'^2}} = \bar{u} + 4.055\sqrt{k} \qquad (2)$$

This relationship was applied everywhere, i.e. over the ridges, as well as on the flat level ground upwind (approach flow).

An approach flow with a mean velocity profile satisfying the logarithmic law was used. The turbulent energy in this flow was assumed constant with height.



RESULTS

Three basic types of two-dimensional single-peaked ridges were examined in the study :

a) escarpments
b) flat-topped ridges (embankments)
c) bell-shaped ridges

Discussion of results in this paper is restricted to those obtained for a bell-shaped ridge with an upwind slope of 0.4. (The upwind slope is defined in the same way as the Australian Standard [1], i.e. the average slope over the top half of the ridge.)

Four types of double-peaked ridge were also studied; however, again, space limitations do not permit discussion of these results in this paper.

The nominal ridge height above flat, level ground was taken as 40 metres. The roughness length used for the results described in this paper was 0.01 metres, giving a Jensen Number (H/z_o) of 4000.

To verify the computational approach adopted in this study, some comparisons were made between previous experimental (model and field studies), numerical and theoretical results for shallow escarpments and bell-shaped ridges [5]. The agreement between the present computations and the previous results was found to be excellent.

In Figure 1, the computed mean wind and peak gust Multipliers, at the crest, for a bell shaped-ridge with an upwind slope of 0.4, are compared with values specified in the Standard. The values specified in the Standard for mean velocities are reasonable, although the assumed linear variation of the Multiplier with height is not a good approximation to that obtained from the computations. The upper height limit, above which topographic effects are neglected, i.e. the height of the 'local topographic zone', is also low in the Standard. However, there is also a significant height range, roughly 0.25 to 1.25 hill heights, in which the Standard is conservative.

For the peak gust Multipliers, the Standard is not conservative. The calculations indicate that there is amplification of the turbulent energy over the ridge, whereas for the Standard, the assumption has been made that the turbulent energy is unchanged as the wind flows over the ridge. The computed values of the Multiplier for peak gust are quite similar to those for mean wind speeds, above about 0.5 ridge heights above ground level.

In Figure 2, the variation of the Multipliers, at a height of 0.125H, (5m when H=40m), with horizontal distance upwind and downwind of the crest is shown. There is a rapid variation in the computed Multipliers over about 1.5 ridge heights of horizontal distance, both upwind and downwind of the crest. Values significantly less than unity occur on both the upwind and downwind sides of the ridge. The linear variation assumed in the Standard is also shown; it appears that, the horizontal extent of the 'local topographic zone' where the Multiplier is taken to be greater than one in the Standard, is too large.

CONCLUSIONS

This study has shown that there may be deficiencies and over-simplifications in the rules for the Multipliers for topographic effects specified in the current Australian Standard for Wind Loads [1] :

a) The linear variation of the Topographic Multipliers above the ground, assumed in the Standard, has the advantage of simplicity for the user, but is an oversimplification of the real situation. At the crest, this assumption produces overestimations of the Multipliers over some height ranges, and underestimations in others.

b) The influence of a steep ridge on the Multipliers is assumed to be negligible above heights greater than 1.67 times the ridge height, in the Standard. However, the computations showed that the region of significant influence extended to greater than 5 ridge heights above the crest. On the other hand, the region of horizontal influence appears to be overestimated by the Standard.

c) The peak gust Multipliers from the Standard are consistently lower than the computed values, whereas the specified magnitudes for the mean wind Multipliers are generally close to the computed values at heights close to the ground.

Although not shown in this paper, the study has also shown that the Multipliers specified in the Standard for escarpments are too low. In fact, the computed Multipliers for the steeper escarpments were not much lower than those obtained for bell-shaped ridges with the same slopes. The effect of topography on thunderstorm downdrafts was also studied, and is discussed in another paper in this Seminar [6].

REFERENCES

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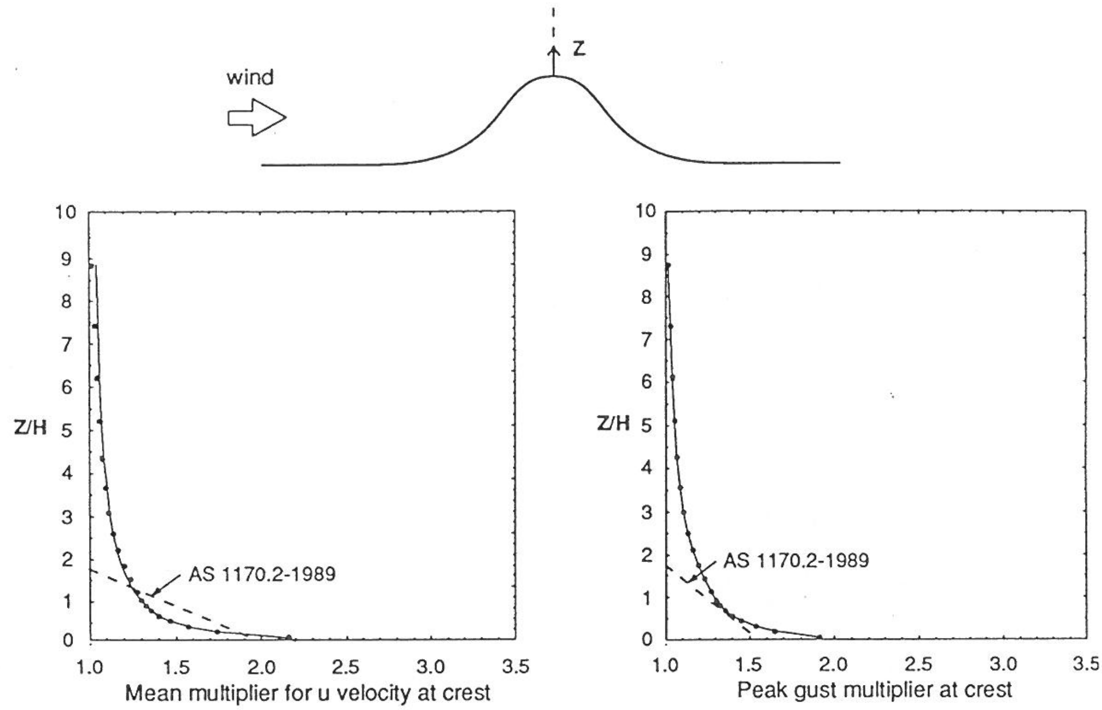

Figure 1. Topographic Multipliers at the crest for flow over a bell-shaped ridge with upwind slope of 0.4

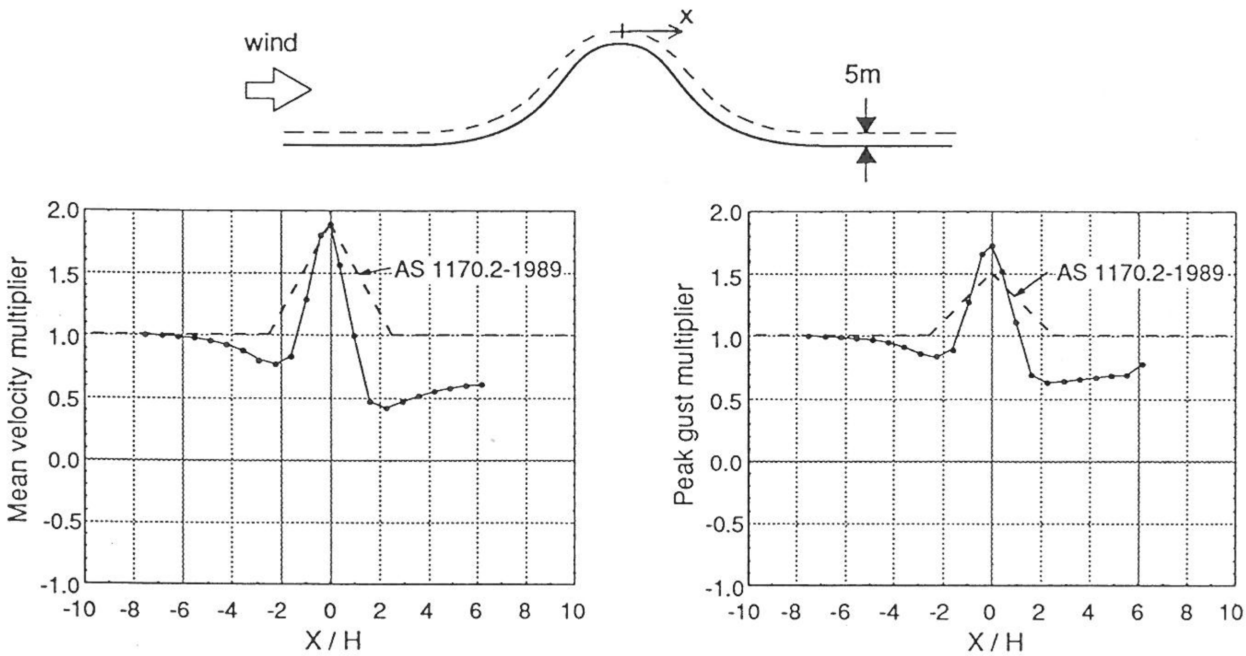

Figure 2. Topographic Multipliers for flow over a bell-shaped ridge with upwind slope of 0.4 (height of 0.125H)